LARGE-SCALE TRANSLOCATION STRATEGIES FOR REINTRODUCING RED-COCKADED WOODPECKERS

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Abstract: Translocation of' wild birds is a potential conservation strategy for the endangered red-cockaded woodpecker (*Picoides borealis*). We developed and tested 8 large-scale translocation strategy models for a regional red-cockaded woodpecker reintroduction program. The purpose of the reintroduction program is to increase the number of red-cockaded woodpeckers by moving subadult birds from large populations to smaller populations that arc unlikely to increase on their own. A major problem in implementing the program is determining where birds will be moved because the larger donor populations cannot supply enough birds for all small recipient populations each year. Our goals were to develop translocation strategies and model which ones would (1) result in the most groups of' woodpeckers in a given amount of time, (2) most quickly reach the goal of at least 30 groups of woodpeckers in every population. and (3) result in the fewest population extinctions. We developed lump-sum strategies that moved all the translocated birds to 1 population each year, and partitioning strategies that divided the birds among several populations every year. In our simulations, the lump-sum strategies resulted in the most woodpeckers for the overall program and the highest number of population extinctions. Partitioning strategies had the lowest population extinction rate but produced the lowest rate of increase in the number of woodpecker groups. The model that partitioned birds to the 6 largest recipient populations with fewer than 30 groups was the best overall strategy for meeting our goals because it reached 30 groups in every population the fastest, produced many birds, and had only a moderate population extinction rate. We suggest that adhering to a single strategy that meets the goals of the participants should simplify the program and reduce its cost.

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James (1995) reported that populations of red-cockaded woodpeckers (*Picoides borealis*) were declining throughout most of their range during the 1980s. Hardwood midstory encroachment around cavity trees causing cluster abandonment (Conner and Rudolph 1989), habitat fragmentation that increased the effects of demographic isolation (Conner and Rudolph 1991, Rudolph and Conner 1994), a paucity of potential cavity trees (Costa and Escano 1989), and net loss of suitable cavities available for nesting have been the primary causes of population decline in Texas (Conner and Rudolph 1995) and throughout the South.

Artificial cavities were developed during the late 1980s to provide suitable cavities for groups of woodpeckers with insufficient cavities for nesting and roosting (Copeyon 1990, Allen 1991). Copeyon et al. (1991) demonstrated that placement of artificial cavities in vacant but suitable habitat in the vicinity of existing red-cockaded woodpecker groups could induce the formation of new social groups. However, the ability to provide adequate numbers of cavities artificially did not solve the dispersal-related problems that existed in most small populations (Saenz et al. 2001).

Reintroduction programs to repopulate historical portions of a species range or to bolster existing small populations have been widely used in other species, but often with poor results (Griffith et al. 1989, Wolf et al. 1996). DeFazio et al. (1987), however, successfully augmented single male red-cockaded woodpeckers with subadult females to fill breeding vacancies. The successful reintroduction of pairs of woodpeckers into unoccupied sites soon followed (Rudolph et al. 1992, Carrie et al. 1999). Fueled by early success, a red-cockaded woodpecker reintroduction effort has been underway in Texas, Louisiana,

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Arkansas, and Oklahoma (the Western Range Translocation Cooperative [WRTC]) since 1995.

The WRTC includes 29 red-cockaded woodpecker populations on 17 different private, state, and federal properties (Table 1). The purpose of the cooperative is to increase the number of red-cockaded woodpeckers by moving subadult birds from large donor populations to smaller recipient populations that are unlikely to increase on their own. To qualify as a donor, populations must have at least 100 groups of woodpeckers (defined as 1 or more birds roosting in a cluster of cavity trees) and demonstrate a stable or increasing population. If the number of groups in a donor population declines, that donor will become ineligible to give birds until the population decline is reversed. This should ensure that no permanent harm would come to the donor population as a result of translocation. Generally, recipient populations must have fewer than 30 groups to receive woodpeckers from donor populations. Mid-sized populations with at least 30 but not more than 100 groups are not eligible to give or receive any birds through translocation. Annually, each donor population usually provides fewer than 40 birds for translocation.

Table 1. Western Range Translocation Cooperative populations ranked by number of groups in 1999. Multiple populations within a single property are assigned individual numbers starting at 1, ranked from smallest to largest.

Rank	Number of groups	Population
1	1	Winn 1[a]
2	3	Ouachita 1[a]
3	3	Champion[a]
4	4	TFS (Fairchild)[a]
5	5	Winn 2[a]
6	5	Winn 3[a]
7	6	Winn 4[a]
8	6	Ouachita 2[a]
9	7	Catahoula 1[a]
10	7	Catahoula 2[a]
11	7	Catahoula 3[a]
12	7	Ouachita 3[a]
13	9	Catahoula 4[a]
14	10	Sabine 1[a]
15	10	Sam Houston 1[a]
16	10	Davy Crockett 1[a]
17	10	Angelina 1[a]
18	11	McCurtain Co.[a]
19	12	Sabine 2[a]
20	12	Temple (TX)[a]
21	14	TFS (Jones)[a]
22	17	Angelina 2[a]
23	21	Temple (LA)[a]
24	25	Peason Ridge[a]
25	38	Davy Crockett 2[b]
26	56	Kisatchie[b]
27	72	Evangeline[b]
28	158	Sam Houston 2[c]
29	224	Vernon/Fort Polk[c]

[a] Populations with fewer than 30 groups are eligible to receive birds from donors.

[b] Populations with 30 or more groups of woodpeckers but fewer than 100 groups are not eligible to give or receive birds in the translocation program.

[c] Populations with 100 or more groups of woodpeckers are eligible to give birds to eligible recipient populations.

In the western portion of the red-cockaded woodpecker's range, removal of subadult birds for translocation to recipient populations has not been shown to negatively affect donor populations. The Sam Houston National Forest has been the primary donor population for the cooperative, donating over 100 birds from 1997 through 1999. During that time, we observed the Sam Houston population grow from 148 to 167 groups of red-cockaded woodpeckers, an 11.4% increase over the 2 years combined. The observed population growth in the Sam Houston National Forest is not surprising. Wherever committed managers have employed the latest management techniques, populations have experienced similar population growth (Conner et al. 2001). For example, the Camp Lejeune Marine Base population in North Carolina has increased an average of 8.4%/yr for the last 7 years, the Croatan National Forest population in North Carolina has increased an average of 8.6% for the last 5 years, and the Eglin Air Force Base population in Florida increased 36% from 1994 through 1999 (Conner et al. 2001).

Approximately 32% of female red-cockaded woodpeckers that fledge each year are incorporated into the population naturally (Walters et al. 1988), whereas up to 70% of translocated birds are incorporated into the population to which they are moved in the WRTC when new inserts are present at recipient sites (Table 2). Most females that fledged the previous nesting season are eligible to be moved because they have an extremely high probability of dispersing naturally from their natal cluster (Walters et al. 1988). Juvenile males, however, may be translocated only if there is at least 1 other nonbreeding male (helper or fledgling) that will remain in the cluster. Forty birds is not necessarily the biological limit that a donor population can provide for translocation, but rather a logistic limit we have observed in the WRTC, based on available per-

Table 2. Reintroduction results on the Davy Crockett, Angelina, and Ouachita National Forests in 1998 and 1999. A bird retained at a site implies that there were birds present in the spring surveys. Percentages from reintroduction sites with at least 1 insert ≤1 year since installation are calculated separately from sites with all inserts >1 year since installation.

		Reintroduction sites with at least one insert ≤1 yr since installation			Reintroduction sites with all inserts >1 yr since installation		
Site	Year	Retained a pair	Retained a single	Failed	Retained a pair	Retained a single	Failed
Davy Crockett	1998	1(100%)	0(0%)	0(0%)	0(0%)	0(0%)	3(100%)
	1999	2(40%)	2(40%)	1(20%)	NA	NA	NA
Angelina	1998	0(0%)	1(50%)	1(50%)	0(0%)	1(25%)	3(75%)
	1999	4(67%)	0(0%)	2(33%)	2(33%)	0(0%)	4(67%)
Ouachita	1998	NA[a]	NA	NA	0(0%)	0(0%)	6(100%)
	1999	NA	NA	NA	3(43%)	0(0%)	4(57%)
Total		7(50%)	3(21%)	4(29%)	5(23%)	1(4%)	20(73%)

[a] NA indicates that no birds were reintroduced into sites of a given treatment that year.

sonnel and funding. A recipient population typically receives at least 6 pairs (I 2 hirds) during a translocation season IO increase the probability of success (Rudolph et al. 1992, Carrie et al. 1999).

Several factors determine which populations receive translocated woodpeckers in a given year. Priorities currently are assigned by consensus of participants at annual red-cockaded woodpecker translocation strategy meedngs. Population size, as described above, is a major factor in the decision process. Often the smallest populations arc considered to he the most vulnerable; therefore, they often are given the highest. priority for receiving woodpeckers. Demographically isolated populations also may he considered more vulnerable than other populations and often are given priority.

Populations with suitable habitat are given priority over populations with poor- habitat. Suitable habitat, a requirement for any recipient population, is open, park-like pine forest devoid of most hardwood midstory. Suitable natural or artificial cavities (preferably new [<1 year old] or being maintained annually) also need to be present at the reintroduction site. Past translocation success may play a part in assigning priorities. Populations that have experienced high woodpecker retention from past reintroductions may be considered a better place to move birds because subsequent translocations also are likely to have a high retention rate.

Population trends of recipient populations also can influence the assignment of' priority. A small, declining population may be given preference to prevent imminent extinction. At the same time, a population that is increasing may be considered a safe place to move birds.

Wc have observed other factors that sometimes play an important role in the assignment of' translocation priorities. Unfulfilled commitments to recipient populations from previous years may determine where some woodpeckers go. Legal considerations, such as lawsuits or timber sales, may block some populations from receiving birds. The commitment of' individual managers to increase their woodpecker population also affects which populations receive birds. Managers demonstrate their commitment or lack thereof hy their efforts to adequately prepare sites to receive birds. Also, eligible recipient populations do not receive birds if their managers do not ask for birds at the annual meetings. Finally, and significantly, availability of funds to operate the program at both the donor and recipient populations is a critical factor tletermining participation in the program. As a result of' the process for assigning priorities and funding limitations, there is no consistent strategy for the woodpecker allocation process.

Only a finite number of' birds can be moved from the limited number of existing donor populations, mainly due to monetary and personnel constraints and concerns about adverse impacts on tht donor populations. Consequently, many recipient populations will not rcccivc birds or do not receive sufficient numbers of birds in a given year. An optimal set of distribution guidelines among populations has yet to be developed for a large-scale red-cockaded woodpecker reintroduction program. Currently, the criteria for determining which populations will receive birds are somewhat arbitrary. We propose and have tested 8 simulation models, based on data from the WRTC, to develop potential strategies for maximizing the efficiency of large-scale red-cockaded woodpecker reintroduction programs.

METHODS

Overview of the Simulation Models

We developed 8 different simulation models of large-scale translocation strategies using STELLA® modeling software (High Performance Systems 1997). In our models, each population was independent of other populations and had its own probability of increasing or decreasing in population size each year, based on population size (see below). Initial population sizes for the simulations were based on the 1999 population status reports from the WRTC populations (Table 1). Simulations were run for each of the 8 models rising a 1-year time-step, for a minimum of 30 years or until all populations (n = 29) reached at least 30 groups, the size at which we believe populations should increase without reintroductions. Population size was the only factor used to determine translocation priorities in each of our models. We tallied the total number of woodpecker groups for all populations at 10, 20, and 30 years in each model to compare the number of groups produced over timr by the strategies and compared the number of years it took for all populations to reach at least 30 groups in the different models. We also determined the mean number of population extinctions that occurred with each model and compared the strategies. We ran the simulations at high (67%) and low (34%) translocation success rates (Table 3) for each model to determine whether the relative effectiveness of each strategy was affected by translocation success. We ran 30 sets of simulations for each model.

Assumptions Common to All Models

(I) Population dynamics anti rates of losses and gains of' woodpecker groups changed as population size changed in the model. The smaller the population, the greater the chance of losing a group annually. Percentages were selected to resemble mean extinction levels predicted by Crowder et al. (1999). All populations were assumed to have a SOO-group carrying capacity because this number of' groups is the most conservative estimate (meaning to err in the favor of the largest number of groups) of' the number of active clusters necessary to achieve the breeding potential of' a recovery population (U.S. Forest Service 1995, U.S. Fish and Wildlife Service 2000).

(a) l'opiilations of 1 to 5 groups had a 40% chance of losing 1 group annually.

(b) Populations of 6 to IO groups had a 30% chance of losing 1 group annually.

(c) Populations of' 11 to 20 groups had a 20% chance of' losing 1 group annually.

(cl) Populations of 21 to 30 groups had a 10% chance of losing 1 group annually.

(c) l'opiilations of' 3 1 to 100 groups increased a conservative (Conner et al. 2001) 5% annually. These populations were no longer eligible to receive translocated pairs of woodpeckers.

(2) Populations of' >100 groups donated 18 pairs (36 birds) of woodpeckers annually. Donating birds was assumed to have no negative effect on donor populations (as observed in the Sam Houston National Forest); therefore, donors also increased at a rate of 5% annually. The size of the donor population did not affect the number of birds donated.

(3) Typic-ally, no fewer than 6 pairs were moved to a recipient population in a given year (the only exception is the quality model).

(4) Approximately 67% of the reintroduced red-cockaded woodpeckers were incorporated into the population when reintroduction sites were equipped with new inserts, and approximately 34% were incorporated when only old inserts were used (Table 2). These success rates

Table 3. Number of population extinctions for each red-cockaded woodpecker translocation model at low (34%) and high (67%) translocation success rates. Simulations preformed using STELLA® modeling software (High Performance Systems 1997).

	Low		High	
Model	$\bar{x}$	SE	$\bar{x}$	SE
Welfare[a]	0.0	0.00	0.0	0.00
Robinhood[b]	0.1	0.56	0.1	0.08
Alternating[c]	0.2	0.08	0.0	0.00
Equality[d]	0.7	0.13	0.0	0.00
Random[e]	2.2	0.16	1.3	0.18
Elitist[f]	7.0	0.16	5.0	0.17
Sheriffs	10.9	0.14	7.7	0.14
Prince John[h]	14.4	0.13	10.7	0.22

[a] The 6 smallest populations received translocated birds.
[b] The single smallest population received all of the available translocated birds annually.
[c] The 6 smallest populations receive translocated birds 1 year, and then in alternate years, the 6 largest recipient populations receive translocated birds.
[d] All translocated birds are divided equally among the recipient populations.
[e] Each year 6 recipient populations are chosen at random to receive translocated birds.
[f] The 6 largest recipient populations receive translocated birds annually.
[g] The single largest recipient population receives all of the translocated birds annually.
[h] The single largest population with fewer that 100 groups receives all of the available translocated birds.

were used as the high and low success rates in all of the models.

All factors, such as suitable habitat, demographics, legal considerations, habitat suitability, and commitment of the managers of recipient and donor populations, were assumed equal.

Partitioning Models

Random Model.—We randomly chose 6 recipient populations (with fewer than 30 groups) each year to receive 6 pairs of woodpeckers from either of'2 donors. When additional populations increased to donor size (100 groups), 3 additional recipient populations received 6 pairs of birds per each additional donor population. The Random Motlcl represents the current process used by the WRTC and serves as a null model for comparisons with the other moclcls.

Equality Model.—All birds available for translocation were divided equally among all the recipient popttlations each year until all populations reached at least 30 groups. Initially, 2 donors provided 36 pairs of' birds. When additional populations increased to donor size, 18 additional pairs of birds per new donor population wet-c divided among the recipient populations. This model violatctl current WRTC guidelines because fewer than 6 pairs of birds were given to each recipient each year.

Welfare Model.—The 6 smallest populations received 6 pairs of' woodpeckers each year from either of' the 2 donor populations. When additional populations became donors, 3 additional recipient populations (the next 3 smallest) received 6 pairs of birds per each new donor population.

Elitist Model.—Each of the 6 largest recipient populations received 6 pairs of woodpeckers each year from either of the 2 donor populations. When more populations became donors, 3 additional recipient popttlations (next 3 largest eligible) received 6 pairs of birds per each new donor population.

Alternating Model.—Each of' the 6 smallest recipient populations in it given year rcccivcd 6 pairs of woodpeckers, and in alternate years, each of' the 6 largest recipient populations rcccivcd 6 pairs of woodpeckers from either of the 2 donor populations. When more populations became donors, 3 additional populations received 6 pairs of birds per each new donor population.

Lump-sum Models

Robinhood Model.—Each year, the smallest recipient population received all of' the birds available for translocation, initially a total of 36 pairs from the 2 donor populations. When additional populations became donor populations, they each contributed an additional 18 pairs/yr to the smallest recipient population.

Sheriff of Nottingham Model.—Each year, the largest recipient population received all of the woodpeckers available for translocation that year, initially a total of 36 pairs from the 2 donor populations. When additional populations became donors, they each con tributed 18 pairs/yr to the largest recipient population.

Prince John Model.—The largest mid-sized population with fewer than 100 groups was given all of the woodpeckers available for translocation each year, initially a total of 36 pairs from the 2 donor populations. When additional populations became donors, they contributed 18 additional pairs/yr to the translocation effort. This model resembled the Sheriff of Nottingham Model, but it focused on producing more donor populations. This model violated current WRTC guidelines because populations with more than 30 groups received birds.

Analyses

We normalized all population-level data by performing a rank-transformation (Conover and Iman 198 1). We compared population levels of all models at 10, 20, and 30 years into the simulations using an analysis of variance and a Scheffe's *F* procedure (a = 0.05). We used the same tests to compare the number of years required for all populations to reach at least 30 groups. The probability of each population becoming extinct during the simulations also was calcrtlatecl for each model and compared among models.

RESULTS

Low Translocation Success Rate

The Elitist Model was the most efficient strategy, when translocation success was low, for t-caching the goal of at least 30 groups of birds in every pop ulation (mean = 25.9 ± 0.1 yr). The Random Model was the second best strategy for reaching the population goal the fastest, taking an average of'28.9 ± 0.1 yr. When low translocation success rates were used, mean times for all of the models to reach the population goal were different (I'< 0.001; Fig. 1a).

The Prince John, Sheriff of Nottingham, and Elitist models resulted in more groups of woodpeckers at year 10 ($P < 0.001$) of the simulations than the other models (Fig. 2a). The strategy of these 3 models was to give birds to the larger populations. At year 20 of' the simulations, the Prince

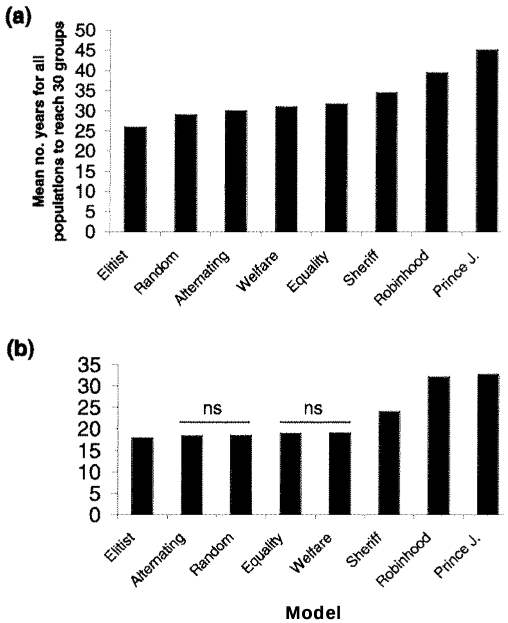

Fig. 1. The bars represent mean number of years for populations in each of the simulation models to reach at least 30 groups (defined as 1 or more birds roosting in a cluster of cavity trees) of red-cockaded woodpeckers in size. Graph (a) represents the results from simulations with a 34% reintroduction success rate, where 34% of the birds donated to a given recipient are incorporated into that population. Graph (b) represents the results from simulations with a 67% reintroduction success rate, where 67% of the birds donated to a given recipient are incorporated into that population. All models under the solid line are not different from each other at the $\alpha \leq 0.05$ level.

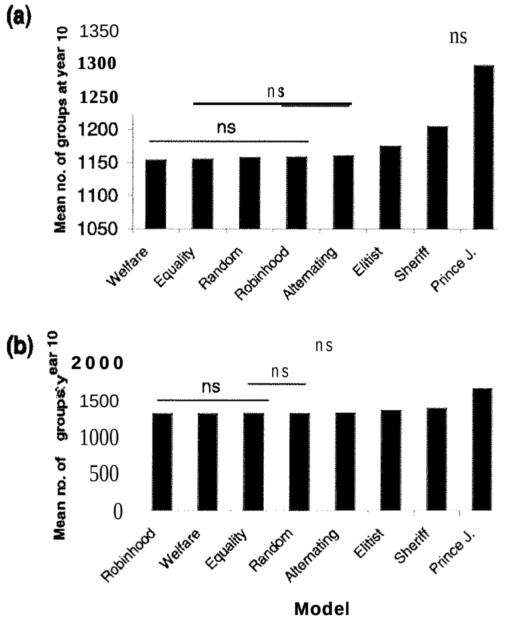

Fig. 2. The bars represent mean number of woodpecker groups (defined as 1 or more birds roosting in a cluster of cavity trees) in the Western Range Translocation Cooperative predicted by each model at year 10 of simulations. Graph (a) represents the results from simulations with a 34% reintroduction success rate, where 34% of the birds donated to a given recipient are incorporated into that population. Graph (b) represents the results from simulations with a 67% reintroduction success rate, where 67% of the birds donated to a given recipient are incorporated into that population. All models under the solid line are not different from each other at the $\alpha \leq 0.05$ level.

John, Sheriff‘ of’ Nottingham, and Elitist mod& again resulted in the most groups of woodpeckers (I’ < 0.001; Fig. 3a). Again at year 30, the Prince John, Sheriff of Nottingham, and Elitist models produced more groups of woodpeckers than the rest of the strategies ($P < 0.001$). The Welfare, Equality, and Robinhood models resulted in thr fewest groups of woodpeckers at year 30 and produced fewer groups than the Random Model ($P <$ O.OOl), the model that best approximates current translocation priorities (Fig. 4a).

The Welfare Model was the only strategy that prevented population extinction during the simulations at the low translocation success rate. The Prince John, Sheriff of Nottingham, and Elitist models produced the highest population extinction rates of all the models (Table 3).

High Translocation Success Rate

When the translocation success rate was high, the Elitist Model was again the fastest strategy ($\bar{x}$ = 17.8 ± 0.1 yr) to reach the goal of at least 30 groups of woodpeckers in every population ($P <$ 0.001) The Random Model reached the population goal faster than the Equality, Welfare, Sheriff of’ Nottingham, Robinhood, and Prince John models, but did not perform better than the Alternating Model (Fig. I b).

At the high translocation success rate, the Prince John Model produced the most groups of woodpeckers for the translocation program after 10 years of sititrtlatiott followed by the Sheriff of’ Nottingham and Elitist models ($P < 0.001$; Fig. 2b). AI year 20 of the simulation, the Prince John, Sheriff of Nottingham, and Elitist models, respectively, still produced the most groups of woodpeckers (I’ < 0.001; Fig. 3b). The Prince John, Sheriff of Nottingham, and Robinhood models—the 3 strategies that gave all available birds to a single population each year—resulted in the most groups of woodpeckers by year 30 of’ the simulation ($P < 0.001$; Fig. 4b). The Welfare

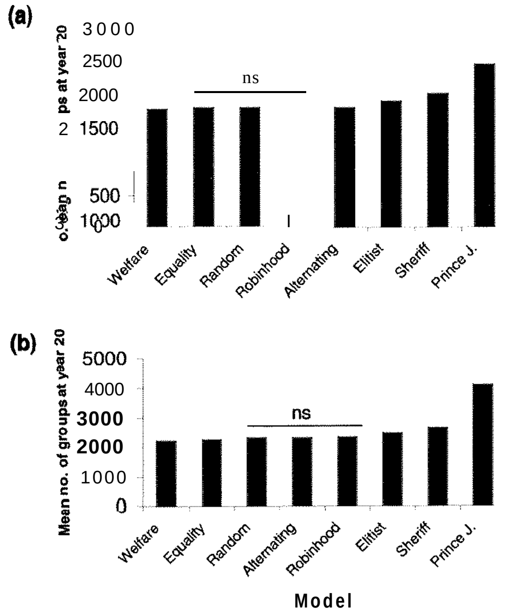

Fig. 3. The bars represent mean number of woodpecker groups (defined as 1 or more birds roosting in a cluster of cavity trees) in the Western Range Translocation Cooperative predicted by each model at year 20 of simulations. Graph (a) represents the results from simulations with a 34% reintroduction success rate, where 34% of the birds donated to a given recipient are incorporated into that population. Graph (b) represents the results from simulations with a 67% reintroduction success rate, where 34% of the birds donated to a given recipient are incorporated into that population. All models under the solid line are not different from each other at the $\alpha \leq 0.05$ level.

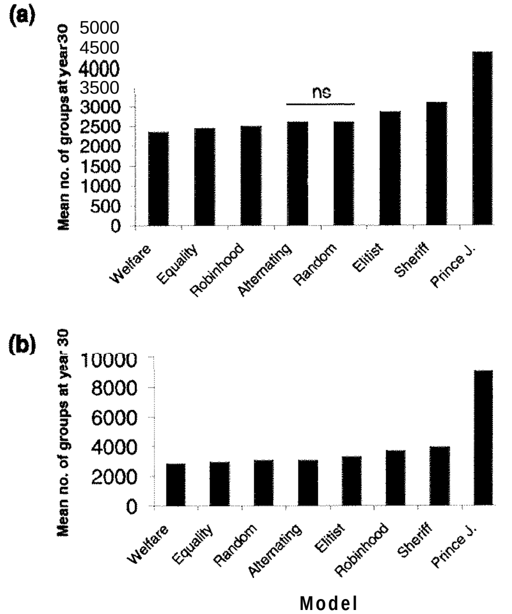

Fig. 4. The bars represent mean number of woodpecker groups (defined as 1 or more birds roosting in a cluster of cavity trees) in the Western Range Translocation Cooperative predicted by each model at year 30 of simulations. Graph (a) represents the results from simulations with a 34% reintroduction success rate, where 34% of the birds donated to a given recipient are incorporated into that population. Graph (b) represents the results from simulations with a 67% reintroduction success rate, where 67% of the birds donated to a given recipient are incorporated into that population. All models under the solid line are not different from each other at the $\alpha \leq 0.05$ level.

and Equality models performed the worst by year 30, producing significantly fewer groups than all other models ($P < 0.001$; Fig. 4b).

Population extinction was completely avoided in the simulations of the Welfare, Equality, and Alternating models at the high translocation success rate. Only 10% of the simulations in the Robinhood Model resulted in a population extinction. The remaining models all had occurrences of extinctions in every simulation. The Prince John Model had the highest extinction rate, followed by the Sheriff of Nottingham, Elitist, and Random models (Table 3).

DISCUSSION

The relative effectiveness of the strategies differed very little at high (67%) and low (34%) translocation success levels. At the low success level, the Elitist Model reached the goal 3 years sooner than the next best strategy, the Random Model. At the high success level, however, the Elitist Model reached the goal >1 year sooner than the 3 next best models (Fig. 1). The difference between 17.8 years (predicted with the Elitist Model) and 18.4 years (predicted with the Alternating model) is small, and managers may choose a less efficient strategy, for example, if there is a desire to reduce the extinction rate. Thus, at higher translocation success rates (where new inserts are used), there is greater latitude in choosing an appropriate strategy.

Additionally, population extinctions on public lands can have serious negative legal and political repercussions on managers that are entrusted with the public's wildlife. Therefore, avoiding extinction is an important consideration for a translocation program. Not surprisingly, simulations run at the low translocation success rate had higher population extinction rates and smaller population sizes than simulations with high translocation success. We suggest that every effort should be made to maximize the reintroduction success rate by providing the newest possible inserts in conjunction with maintaining optimal red-cockaded woodpecker habitat (Conner and Kudolph 1989) with minimal hardwood midstory vegetation. A high reintroduction rate will not only increase the flexibility of a translocation program, but it will also increase the rate at which we recover the species.

The lump-sum strategies, where all translocated birds were given to a single population each year (Sheriff of Nottingham, Robinhood, and Prince John models), are likely to be quite effective in producing large numbers of woodpecker groups in a relatively short time because these strategies focus on fast growth of the larger populations that result in additional donor populations very early in the simulations. However, they are not very realistic options as actual strategies. The logistics of I recipient preparing the adequate number of reintroduction sites makes the lump-sum strategies impractical. Another drawback to these strategies is that only 1 population receives birds in a given year, which greatly increases the probability that some smaller populations will become extinct.

In contrast, partitioning strategies (Elitist, Alternating, Welhre, and Equality models) are not as likely to produce large numbers of woodpecker groups because the main advantage of these strategies is the ability to quickly increase the size of' the smaller populations, not to produce donors. These strategies will be more easily implemented since recipients will need to prepare only a modest number of reintroduction sites; thus, it is more likely they will be accepted as viable options. In addition to being more logistically feasible, more recipients will be involved every year, and these strategies will reduce the amount of time recipient populations have to wait to receive birds, which should raise morale and interest in the program.

The strategies that regularly gave woodpeckers to the smaller populations, such as the Welfare, Robinhood, Alternating, and Equality models, experienced low extinction rates, while strategies chat gave birds only to the larger populations had numerous extinctions. The Prince John and Sheriff of Nottingham models, despite their potential for producing the most birds over time, had such a high incidence of extinction that their suitability as a viable conservation strategy is doubtful.

Population extinction can result in the loss of genetic diversity. An important component during the recovery of an endangered species is the preservation of' its evolutionary potential. Toward this goal, we need to identify the evolutionary significant units, such as distinct phenotypes, populations with a long-term history of geographical isolation, and populations at the extremes of their ranges (Meffe and Carroll 1997). Currently, no unique red-cockaded woodpecker phenotypes have been described anywhere in the western portion of its range. Population isolation in the region is relatively new and is the result of relatively recent (<100 yr) forest removal (Cornier and Rudolph 1991). Extinction of some isolated populations in the western portion of' its range would likely not have any greater negative effect on the evolutionary potential than would occur with swamping from an infusion of the large numbers of translocated individuals that would be required to recover the populations. The massive translocation effort that would be required to recover the species or to maintain sink populations would likely dilute any unique alleles present.

Populations with a minimal land area available for recovery could slow the success of the translocation program. For instance, populations residing in forests that have small land areas and a carrying capacity of fewer than 30 groups would likely require occasional translocations to maintain their probability of persistence (Crowder et al. 1999). These populations could be considrred sinks in perpetual need of translocated woodpeckers. If such sink populations continually require birds from the translocation program, they could slow the recovery progress of populations that do have the potential to exceed the minimum population threshold. Populations that are deemed to be sinks might be moved to the bottom of the translocation priority list and receive birds only after all other populations that have the potential to become sell&staining exceed the population-size threshold.

There is little doubt that the technology exists to recover the red-cockaded woodpecker, often at a rapid rate (Conner et al. 2001). Translocation is just 1 of several valuable tools available to managers committed to increasing their populations. However, translocation alone is not adequate, and managers must be fully committed to maintaining suitable habitat and cavity availability (Conner et al. 2001).

Translocation is a much more complex endeavor than some of the other management techniques because of the numerous competing interests, such as the donor and recipient populations. Simulation models can be valuable tools that offer guidance in our decisions about resource allocations. In this case, results of simulations of different translocation strategies can providc important information for selection of a strategy that optimizes the use of the limited number of' woodpeckers available for translocation. However, goals of the recovery program must first be identified. In the case of the WRTC, quickly reaching a level where all populations are self-sustaining (30 or more groups), attaining the highest possible number of' woodpecker groups, anti reducing population extinctions arc all reasonable goals. Obviously, real-world constraints and conflicting goals will add complexity to conclusions provided by any model. Our models provide a framework that, along with consideralion of' other critical factors, c-ail be used to help select preferred strategies for attaining a goal or a combination of goals.

MANAGEMENT IMPLICATIONS

We suggest that thr Elitist Model may be the best translocation strategy for a long-term, large-scale red-cockaded woodpecker translocation program because it provides the most efficient approach to increase recipient populations to a size at which they become self-suslainirig. The Elitist Model also results in a relatively large number of' groups and ii relatively low extinction rate compared with all other strategies. This strategy stays within the guidelines established by the U.S. Fish and Wildlife Service for translocation programs by providing birds only to recipients with fewer than 30 groups of' birds and by providing 6 pairs (the U.S. Fish anti Wildlife Service guidelines require at least 5 pairs) of birds to each recipient. A potential disadvantage of the Elitist Model is that somc populations may become extinct before they are considered for translocations. Genetic variability could be lost in the process. We suggest, however, that the potential benefits to the recovery effort, as a whole, outweigh the unlikely potential for losses of' genetic diversity.

We also suggest there may be advantages to selecting and adhering to a single strategy because it can reduce the uncertainty of which populations will receive birds each year. If' population size is the primary criterion for selecting the recipients each year, these recipients can adequately prepare for translocation well in advance. Eligible recipient populations that are not scheduled to receive birds in a given year will know well in advance, perhaps up to several years, when birds arc likely to arrive. These recipients could then prioritize their management practices, for example, to maintain the appropriate midstory and herbaceous layer conditions needed by the woodpecker and provide recruitment stands for natural expansion. Although we suggest the use of a single strategy as the most prudent approach, some flexibility will be necessary to maximize the efficiency of the program, assure genetic diversity, account for fluctuating budgets, and meet the diverse needs of the participants in the program.

To the credit of the agencies, organizations, and individuals involved, we have witnessed that the current system of bird allocation (Random Model) has proven to be successful in the western range, accounting for stabilizing and increasing populations on various private, state, and federal lands. With additional insight gained from defining and simulating translocation strategies, managers can achieve even greater success in future translocation efforts.

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